”SUPER SPIKES” INCREASE 40-M SPRINT PERFORMANCE IN NATIONAL-LEVEL WOMEN ATHLETES

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The aim of this work was to quantify the effect of adding carbon fiber plates in the midsole of spike shoes (*i.e.*, "super spikes") on 40-m sprint performance. Eight female national level athletes completed four 40-m sprints using two different types of footwear (*i.e.*, traditional spikes and “super spikes”). The main results showed an improvement of 0.6% in performance when the athletes wore "super spikes" (*i.e.*, 0.031 s in 0-40 m), mainly in the flying phase (*i.e.*, 0.026 s in the 20-40 m), which could be due to an increase in leg and vertical stiffness (*i.e.*, greater in the "super spikes") and a reduction in the ground contact time (*i.e.*, less time with “super spikes”). Also, this improvement seems to be related to the sprinter’s performance level. In conclusion, wearing "super spikes" has a positive effect on 40-m sprint performance compared to conventional spikes.

KEYWORDS: biomechanics, materials, spike shoes, athletics, female.

INTRODUCTION: There have been numerous technological advances in the field of sports footwear in recent years, as the biggest sportwear brands have developed new lighter and stiffer materials for their shoes (Healey et al., 2022). One of the sports where these innovations have had a significant effect on performance has been athletics, where their implementation has led to an improvement in both men and women’s performance on long-distance races (Healey et al., 2022). These improvements are mainly explained by the inclusion of carbon fiber plates in the midsole of the shoes, that increase the stiffness, and therefore, reduce the loss of energy of the metatarsophalangeal joint during the midstance phase (Stefanyshyn, & Nigg, 2000). The number of scientific studies focused on the effect of this technology on marathon performance is quite extensive (Bermon et al., 2021). A significant improvement in the top 20 season bests for both men and women has been observed since the inclusion of this technology (Bermon et al., 2021). Likewise, it has also been detected a 0.68% improvement in the fininshing times of the marathon runners that changed their conventional running shoes for this type of footwear (Rodrigo-Carranza et al., 2021). Regarding track and field events, new types of spike shoes that also have a carbon fiber plate embedded within the midsole (*i.e.*, “super spikes”) have been developed in recent years. These new technologies are expected to result in mechanical advantages, such as improved energy return or increased ankle push off moments. However, their effect on performance in track and field events remains to be investigated (Healey et al., 2022). Therefore, the main aim of this work is to analyze the effect of these new technologies on 40 m sprint performance.

METHODS: The participants of this study were eight Under-20, Under-23, and senior national-level female sprinters (age: 21.3 ± 3.4 years, weight: 55.4 ± 5.3 kg, height: 161.3 ± 4.1 cm, 100-m Personal Best: 12.36 ± 0.33 s). All of them were informed of the benefits and risks of the investigation and written signed consent was obtained.
The procedure consisted of four 40 m sprints using two different spike shoes in a randomized order, with full recovery between efforts. Therefore, two sprints were performed using traditional spikes and the other two using a type of spike shoes that feature a full-length carbon fiber plate in the midsole (*i.e.*, Nike Air Zoom Maxfly), named “super spikes”, as previous studies did (Hébert-Losier & Pamment, 2022). The 10, 20, 30 and 40 m split times were recorded using a timing system (DSD Laser System, DSD Inc., León, Spain) made up of four pairs of laser sensors, and a set of starting blocks with a contact sensor (AC010, Mondo Inc., Alba, Italy) that detected when the front foot left the blocks (*i.e.,* time recordings started when the front foot left the blocks) (Figure 1). Likewise, video recordings of the first 10 of the acceleration phase (0-10 m) and the last 10 m of the flying phase (30-40 m) of the 40-m sprint were made from the sagittal plane at a speed of 240 fps (IPhone SE 2020). The software

Kinovea (v.0.9.5) was used to obtain the stride frequency (Hz), stride length (m) and ground contact time (s) values. The time the athlete took to take six steps was used to calculate stride frequency. To obtain stride length, the distance that the athlete covered in six steps was obtained and divided by the number of steps. Finally, ground contact time was calculated as the average ground contact time of six steps. In addition, leg stiffness and vertical stiffness values were obtained during the flying phase (Morin et al., 2005).

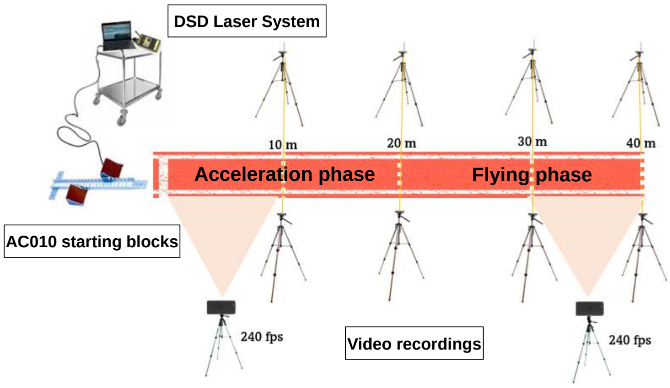

Figure 1: Schematic representation of the biomechanical analysis

The software SPSS V.21.0 (SPSS, Inc., Chicago, IL, USA) was used for the statistical analysis. Wilcoxon paired test was used to analyze the effect of the type of shoe (*i.e.,* conventional *vs.* "super spikes") on the analyzed variables of the sprint. Mann Whitney U test was used to compare between groups of athletes, which were classified according to the percentile 50 in relation to their 100-m Personal Best. Spearman test was used to analyze the correlations between measured variables. A value of P< 0.05 was considered statistically significant.

RESULTS: Sprint performance (*i.e.* 40-m time) significantly decreased 0.031 s (0.6%) when the sprinters wore "super spikes" (P= 0.02; Table 1), and all but one of the participants improved their 40-m time. The four 40-m slowest sprinters improved 0.9% their performance whereas the four faster ones improved 0.2% (P= 0.02; 0.050 ± 0.014 *vs*. 0.010 ± 0.007 s, respectively). Significant correlations were observed between the 40 m "super spikes" time improvements (s) and the sprinters 100 m Personal Bests' (P= 0.01; r= 0.83).

Table 1: Biomechanical variables (Mean ± SD) analyzed during the 40-m sprint (acceleration and flying phases) wearing two types of spike shoes (traditional spikes and "super spikes").

	Variable	Traditional spikes	"Super spikes"
Sprint performance (0-40 m)	Time (s)	5.495 ± 0.153	5.464 ± 0.140*
Acceleration phase (0-10 m)	Time (s)	3.088 ± 0.081	3.083 ± 0.080
	Stride frequency (Hz)	4.50 ± 0.25	4.48 ± 0.19
	Stride length (m)	1.21 ± 0.09	1.22 ± 0.09
	Ground contact time (s)	0.148 ± 0.006	0.153 ± 0.005
Flying phase (30-40 m)	Time (s)	2.407 ± 0.080	2.381 ± 0.066*
	Stride frequency (Hz)	4.62 ± 0.18	4.64 ± 0.14
	Stride length (m)	1.80 ± 0.06	1.81 ± 0.05
	Ground contact time (s)	0.105 ± 0.006	0.103 ± 0.004*
	Leg stiffness ($kN \cdot m^{-1}$)	12.34 ± 1.53	13.26 ± 1.72*
	Vertical stiffness ($kN \cdot m^{-1}$)	131.29 ± 20.19	138.98 ± 18.62*

**Significant differences between traditional spikes and "super spikes" (P<.05).*

Table 1 shows that during the acceleration phase (0-10 m), the type of spike shoe did not have an effect on performance (P= 0.58), as there was only an improvement of 0.005 s (0.1%). No statistically differences were found in the stride frequency (P= 0.92), stride length (P= 1.00), or ground contact time (P= 0.07). In contrast, during the flying phase (30-40 m), the type of spike shoe had an effect on performance (P= 0.01), as an improvement of 0.026 s (0.5%) was observed with “super spikes”. No statistical differences were found in the stride frequency (P= 0.61) or stride length (P= 0.26), even though both variables slightly increased when the participants wore “super spikes”. However, ground contact time significatively decreased (P= 0.02) and both leg (P= 0.02) and vertical stiffness (P= 0.02) increased 7.5% (95%CI = 0.79-14.45) and 5.9% (95% CI=0.97-11.59), respectively, with “super spikes”.

DISCUSSION: The main outcome of this study was to obtain a 0.6% improvement in sprint performance (*i.e.*, 0.031 s in 40 m) when the athletes wore “super spikes”. This improvement was smaller than the 1.8-2.6% observed when analyzing the effect of traditional spikes compared to road-running shoes over a similar 40-m sprint (Jiménez & García-López, 2017; Corbí et al., 2018). However, in comparison to these previous studies, this improvement (0.6%) was like the effect of adding 70-100 grams to each spike.
When performing the analysis by phases of sprinting, most of the 40 m time improvement (0.026 s) was obtained during the flying phase (*i.e.*, 0.5% in 20-40 m), whereas there was almost no improvement in the acceleration phase (*i.e.*, 0.1% in 0-20 m). Although the previously mentioned studies (Jiménez & García-López, 2017; Corbí et al., 2018) observed time improvements during both phases, they could not dissociate the benefits of using spikes from those of the shoe stiffness. In our study, the athletes used the same spikes during all tests, so the only difference between the shoes was in their stiffness (*i.e.*, higher in “super spikes”), which could explain why we only found differences in the flying phase. Therefore, it is possible that the use of spikes in the running shoes is more important during the acceleration phase (Kawamori et al., 2013), while the stiffness of the shoe has more relevance during the flying phase. Also, if the 20-m flying phase improvements observed were extrapolated to a 100-m sprint event, an improvement around 0.100 s could be possible (*i.e.,* 4 times the 20-m flying phase improvement). Further studies should analyze the effect of “super spikes” on running tests of a longer distance to verify this suggestion.
Although ground contact time decreased and both vertical and leg stiffness increased in the flying phase, no significant differences were found in stride frequency and stride length (Table 1). However, the combination of the small increases of the last two variables resulted in the improvement of performance during this phase. It is also important to note that these improvements in leg and vertical stiffness (7.5% and 5.9%, respectively) are higher than the measurement error stated by Morin et al. (2005) for overground running condition (i.e., 2.3% for vertical stiffness and 2.5% for leg stiffness). Several authors have stated that during flying sprint the legs act as a spring loaded with the body mass, which has been named as “spring-mass model” (Brughelli & Cronin, 2008; Morin et al., 2005). The observed improvements during the flying phase in ground contact time and both vertical and leg stiffness could be related to the higher capacity of the “super spikes” to store and return elastic energy as velocity increases (Bergamini, 2011). On the other hand, a significant correlation between the 40-m “super spikes” time improvement and the 100-m Personal Best was also observed, meaning that the slower sprinters benefit more from wearing “super spikes” than faster sprinters. Besides, the four athletes with the worst 100-m Personal Bests improved more their 40-m time when they wore the "super spikes" than the four athletes with the faster Personal Bests. However, to the best of our knowledge, no previous study analyzed the differential effect of “super spikes” according to the performance level. It could be suggested that the faster athletes may still be accelerating during this phase, and subsequently, contacting the ground in a different foot and leg position than the slower athletes. Another explanation could be that the faster sprinters have already developed enough stiffness so the one provided by the “super spikes” is not useful for them, or that the slower sprinters lack the capacity to make use of the “super spikes” longitudinal bending stiffness due to missing plantar flexor or toe flexor strength (Willwacher, 2016).
Lastly, a smaller metatarsophalangeal joint deformation during the mid-stance phase was observed when the athletes wore “super spikes”. This could be explained as well by the fiber plate embedded within the midsole, as it increases the spike shoes’ stiffness and stores more elastic energy than traditional spike shoes (Stefanyshyn, & Nigg, 2000). However, measuring the level of deformation of said joint was challenging, so this result is purely qualitative.

Therefore, future studies should perform a quantitative analysis of this variable. In addition, the main limitation of our study was obtaining the variables of stride frequency, stride length, and ground contact time from the video analysis, which could lead to some measurement errors (i.e., errors in estimations of touch-down and take-off frames). Future studies should also take this aspect into account when determining their methodology.

CONCLUSION: "Super spikes" have a 0.6% beneficial effect on 40-m sprint performance of national-level female athletes, which is similar to the effect of adding 70-100 grams to each spike observed by previous studies. Furthermore, this improvement occurs mainly in the flying phase (*i.e.*, 0.031 s in 20-40 m), so a time improvement of 0.100 s in a 100 m sprint might be possible. The improvement observed on this phase could be justified by the increase in both leg and vertical stiffness and the lower metatarsophalangeal joint deformation observed when the athletes wore "super spikes". Also, this improvement seems to be related to the sprinter's performance level, as the slower runners improved their time more than the fastest ones. The main practical application of this research is that "super spikes" footwear improve athletic performance in track and field events involving flying sprints. Further studies should also use a sample of athletes of different performance levels as well as carry out a quantitative analysis of the effect of "super spikes" on the metatarsophalangeal joint deformation during the mid-stance phase.

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